Development of a Laboratory Procedure to Evaluate the Influence of Aggregate Type and Mixture Proportions on the Frictional Characteristics of Flexible Pavements

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Acknowledgement

This work was supported by the Iowa and Indiana DOTs through the Joint Transportation Research Program at Purdue University

This presentation reflects the views of the authors, not necessarily the official views of the sponsors.
Background

● Pavement friction is function of microtexture and macrotexture.
  ◆ Microtexture - provided by aggregate surface
  ◆ Macrotecture - determined by overall properties of the pavement surface (NMAS and gradation of aggregates, binder content, etc.)

● Friction at the tire-pavement interface is caused by:
  ◆ Adhesion - between tire and surface (microtexture)
  ◆ Hysteresis - deformation of tire around surface irregularities (macrotecture)
Designing for Pavement Friction

- Most states, including Indiana and Iowa, specify allowable surface aggregates by type based on historical usage and aggregate tests.
  - Useful, but agg tests do not consider macrotexture.
- Typical Superpave mixes (in Indiana and Iowa) tend to have increased macrotexture over previously used dense mixes.
Impetus for the Study

- Widely available aggregates in the region are carbonates
  - Tend to polish
- Polish resistant aggregates are not readily available and must be hauled in -- $$$.
- Coarser texture of Superpave mixes may reduce the need for high microtexture aggregates.
Problem Statement

- There is a need to assess and optimize the combined effects of micro- and macrotexture in a mix to maintain adequate friction. So, this study aimed to:
  - Develop/modify a laboratory device (and testing procedure) to accelerate polishing of HMA surfaces,
  - Evaluate the influence of asphalt mix composition on frictional characteristics of HMA, and
  - Develop model for prediction of frictional characteristics from the laboratory test.
Variables Studied

3 gradations: fine (F), coarse (C) and S-shaped (S)

2 NMAS: 9.5 and 19 mm

2 high friction aggregate types (FAT): steel slag (SS) and quartzite (Q)

3 carbonate aggregate types (CAT): dolomite (D), soft limestone (SL) and hard limestone (HL)

7 levels of friction aggregate content (FAC): 0, 10, 20, 40 and 70%
Matrix I

NMAS: 9.5 mm

20% Q

20% SS

NMAS: 19.0 mm

20% Q

20% SS

* -same as for 20%Q, NMAS 9.5 mm

FAT

CAT

G

D

SL

HL

C

C

C

S

S

S

F

F

F

-same as for 20%Q, NMAS 9.5 mm
Matrix II
NMAS: 9.5 mm
G: S
CAT: D

FAT
Q
10%
20%
40%
70%

FAC
0% FAC
10%
20%
40%
70%

SS
10%
20%
40%
70%
Matrix III
NMAS: 9.5 mm
FAT: SS
G: C

CAT
D
10%

FAC

SL
10%
20%

HL
10%
20%

-cell tested as a part of matrix I
Gradations

19 mm

9.5 mm

Cumulative % Passing

Sieve size, mm

Fine gradation, F
Coarse gradation, C
S-shaped gradation, S
Mixture Designs

- Superpave mix designs conducted for each gradation and NMAS
- Gradations constant to ±2.5%
- Aggregate type within ±5% on each sieve
- Binder content adjusted to account for changes in absorption while maintaining 4% voids
- Mixture volumetrics verified at Ndcs.
- Lab mixes produced, conditioned, cooled, reheated and compacted into slabs.
Dynamic Friction Tester (DFT)

DFT – dynamic friction at 20 km/h (DF20)
Circular Track Meter (CTM)

CTM – Mean Profile Depth, mm

IFI \((F_{60}, S_p)\)

\[
F_{60} = 0.081 + 0.732D F_{20} e^{S_p}
\]

\[
S_p = 14.2 + 89.7MPD
\]
Specimen Fabrication
46 specimens were tested...
Circular Track Polishing Machine
Friction/Texture Measurements

- Polisher stopped periodically to measure texture and friction,
- Two texture and friction measurements were conducted at the beginning of polishing and after each stop,
- Polisher stopped after the specific cumulative number of wheel passes from 1500 to 165,000 (19.5 hrs)
Texture and Friction (DF20)
IFI (F60)

(b) 0.6

F60

0.5

0.4

0.3

0.2

0

50

100

150

no. wheel passes, 10^3

North Central Superpave Center
Proposed Polishing Model
Approach to Data Analysis

- Model evaluates
  - Rate of polishing (friction change)
  - Terminal value of friction
- Best handled by analyzing data in the three “friction” zones mentioned previously
- Model parameters found by minimizing the sum of square errors (SSE)
Polishing Rate -- Matrix I

CAT: sample order in each section: D, HL, SL
Terminal Friction Levels - I

CAT: sample order in each section: D, HL, SL
Polishing Rate with FAC - II

Friction aggregate content (FAC)

- x: FAT=SS
- ◊: FAT=Q
- ●: no FAT
Terminal Friction - II

Friction aggregate content (FAC)

0%  10%  20%  40%  70%

x: FAT=SS
◊: FAT=Q
●: no FAT

Terminal friction level, F60@x1
Summary and Conclusions

- Laboratory device and testing procedure to accelerate polishing was developed and tested.
- Combined effects of aggregate microtexture and mixture microtexture can be measured and used to predict polishing rate and terminal friction levels.
Summary and Conclusions

- Increasing friction aggregate content improves frictional properties.
- 9.5mm NMAS mixes had higher resistance to polishing, but lower overall friction level.
- In general, mixes with “soft” limestone, had lower friction than dolomite and hard limestone mixes.
Summary and Conclusions

- Type of friction aggregate influences polishing rate and terminal friction.
- Polishing and testing techniques appear very promising.
Future Research

- Additional field verification and correlation with lab tests (underway)
- Determine F60 flag value (underway)
- Refine specimen fabrication technique and variability (underway)
- Define limits for polishing rate and terminal friction levels